US-PAT-NO: 6440823

DOCUMENT-IDENTIFIER: US 6440823 B1

TITLE: Low defect density (Ga, Al, In)N and HVPE process for making same

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Brief Summary Text - BSTX (18):

Poroswski, et al. (S. Poroswski, et al., Mat. Res. Soc. Symp. Proc. 449 (1997) 35) report **free-standing** GaN as large as 0.7 cm.sup.2 by high pressure sublimation.

Brief Summary Text - BSTX (31):

It is another object of the invention to provide a low defect density, large area, substantially crack-free (Ga,Al,In)N material on lattice mismatched materials which are removable to enable low defect density, large area, substantially crack-free, **free-standing** (Ga,Al,In)N material.

Brief Summary Text - BSTX (37):

In one aspect, the invention relates to a low defect density, large area, substantially crack-free (Ga, Al, In)N material. Such material may be of a **free-standing** type, or alternatively may be supported on a lattice-mismatched template material.

Brief Summary Text - BSTX (50):

The substrate upon which the (Ga,Al,In)N material is deposited can be tailored to enhance the properties of the (Ga, Al, In) N material. The substrate material can be chosen so that it can be easily removed in situ or ex situ, to yield the (Ga, Al, In) N material as a **free-standing** film, by a process as described in co-pending U.S. patent application Ser. No. 08/955,168 filed Oct. 21, 1997 in the names of Michael A. Tischler, Thomas F. Kuech and Robert P. Vaudo for "Bulk Single Crystal Gallium Nitride and Method of Making the Same," and U.S. Pat. No. 5,679,152 issued Oct. 21, 1997; U.S. application Ser. No. 08/984,473 filed Dec. 3, 1997; U.S. provisional patent application No. 60/031,555 filed Dec. 3, 1996 in the names of Robert P. Vaudo, Joan M. Redwing, Michael A. Tischler and Duncan W. Brown, the disclosures of which are hereby incorporated herein by reference in their entireties.

Drawing Description Text - DRTX (10):
FIG. 9 is a schematic representation of high voltage GaN Schottky rectifier fabricated with **free-standing** HVPE GaN material.

Detailed Description Text - DETX (18):
The (Ga, Al, In)N material may be initially formed on a substrate, and the substrate may be removed to provide a **free-standing** (Ga, Al, In)N article. The **free-standing** (Ga, Al, In)N article may then serve as an independent base substrate for device fabrication. The **free-standing** (Ga, Al, In)N article may be further treated to remove the initial monolayers of the (Ga, Al, In)N material to effect a substrate with a lower defect density than that claimed herein.

Detailed Description Text - DETX (21):
As another example, the substrate may be removed from the (Ga, Al, In)N material by subsurface implantation of hydrogen or other suitable implantation species in the substrate before formation of the (Ga, Al, In)N material thereon. The substrate/(Ga,Al,In)N material may thereafter be subjected to elevated temperature and pressure conditions suitable for causing the implanted hydrogen to exert pressure on the interface between (Ga,Al,In)N material and the substrate to cause the separation of the (Ga,Al,In)N material and the substrate from one another, to yield a **free-standing** (Ga, Al, In)N material.

Detailed Description Text - DETX (24):
The resulting separated and **free-standing** (Ga,Al,In)N material may be of any suitable thickness, as for example a thickness, e.g., >100 .mu.m, suitable for use of the (Ga,Al,In)N material as a bulk substrate for device fabrication, or at lesser thicknesses as a constituent layer for use in device applications, e.g, as a layer to be bonded or otherwise provided on an underlying substrate or device precursor structure.

Detailed Description Text - DETX (25):
FIG. 4 shows a low magnification optical photograph of a resulting large-area crack-free GaN material of 250 .mu.m thickness produced according to the present invention. Implementation of the thermal decomposition procedure was carried out using a Q-switched Nd:Yag laser (wavelength=355 nm). The **free-standing** GaN material shown in this photograph contains approximately 10 cm.sup.2 of crack-free material in the right hand portion (grid elements in the photograph are 1 mm.times.1 mm) and has a defect density less than 5.times.10.sup.6 cm.sup.-2 at the upper surface of the GaN. The GaN shown in FIG. 4 is transparent and the surface is specular to the eye. The resulting wafer is not fragile, can be easily handled and cleaved. Such **free-standing**

films represent a significant advance in the art of production of (Ga, Al, In)N materials. The substrate upon which the (Ga,Al,In)N material is deposited can be chosen to facilitate substrate removal.

Detailed Description Text - DETX (28):
As used herein, the term "large area" refers to a material having a surface area at least 1 cm.sup.2., more preferably greater than 10 cm.sup.2, and most preferably greater than 20 cm.sup.2. The term "**free-standing**" means that the material is self-supporting in character, and does not have an associated substrate or support in such form.

Detailed Description Text - DETX (77):
As another illustrative example of a device embodiment of the present invention, FIG. 9 is a schematic representation of a high power GaN Schottky rectifier fabricated on **free-standing** GaN.

Detailed Description Text - DETX (84):
The present invention provides a technique for producing large area, substantially crack-free, low defect density, **free standing** (Ga, Al, In)N substrates, e.g., of GaN.

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DOCUMENT-IDENTIFIER: US 6319742 B1

TITLE: Method of forming nitride based semiconductor layer

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Abstract Text - ABTX (1):
A **GaN** layer is grown on a sapphire substrate, an SiO.sub.2 film is formed on the **GaN** layer, and a **GaN** semiconductor layer including an MQW active layer is then grown on the **GaN** layer and the SiO.sub.2 film using **epitaxial lateral overgrowth**. The GaN based semiconductor layer is removed by etching except in a region on the SiO.sub.2 film, and a p electrode is then formed on the top surface of the GaN based semiconductor layer on the SiO.sub.2 film, to join the p electrode on the GaN based semiconductor layer to an ohmic electrode on a GaAs substrate. An n electrode is formed on the top surface of the GaN based semiconductor layer.

Brief Summary Text - BSTX (15):
When the **epitaxial lateral overgrowth** is used, a **GaN** crystal of high quality having no dislocations can be formed on the SiO.sub.2 films 90.

Drawing Description Text - DRTX (20):
FIG. 19 is a schematic sectional view showing the steps of a conventional method of forming a **GaN** based semiconductor layer using **epitaxial lateral overgrowth**;

Detailed Description Text - DETX (3):
As shown in FIG. 1, an AlGaN buffer layer 2 is first formed on a sapphire substrate 1, and an undoped GaN layer 3 is grown on the AlGaN buffer layer 2. An SiO.sub.2 film 4 having a predetermined width is formed on the **GaN** layer 3, and an n-**GaN** layer 5 is then grown on the **GaN** layer 3 and the SiO.sub.2 film 4 using **epitaxial lateral overgrowth**.

Other Reference Publication - OREF (5):
Jpn. J. Appl. Phys. vol. 36 (1997), pp. L899-L902. Part 2, No. 7B, Jul. 15, 1997. Akira Usui et al., "Thick GaN Epitaxial Growth with Low **Dislocation Density** by Hydride Vapor Phase Epitaxy".